The University of Chicago

THE CALCIUM PHOSPHORUS METABOLISM OF NORMAL YOUNG WOMEN AND THE EFFECT OF VITAMIN D ON THE UTILIZATION OF THESE ELEMENTS

A DISSERTATION SUBMITTED TO THE FACULTY OF THE DIVISION OF THE BIOLOGICAL SCIENCES IN CANDIDACY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF HOME ECONOMICS
AND HOUSEHOLD ADMINISTRATION
1937

By
MARGARET LEE MAXWELL

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ACKNOWLEDGMENT

The author wishes to express gratitude to Dr. Lydia J. Roberts and Dr. Margaret Hessler-Brooks for valuable counsel and critical reading of the text; to the group of University of Chicago students who served as subjects for their willing, co-operative service; and to the American Home Economics Association for the Ellen H. Richards Fellowship, which aided in partially financing the study.

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THE CALCIUM-PHOSPHORUS METABOLISM OF NORMAL YOUNG WOMEN AND THE EFFECT OF VITAMIN D ON THE UTILIZATION OF THESE ELEMENTS

This article reports the results of a long-time calcium phosphorus balance study on seven adults. It was carried out for the purpose of determining the normal variation in such balances on a constant diet, and the effect on them of vitamin D.

REVIEW OF LITERATURE

Calcium-Balance Studies

The literature of calcium-balance studies conducted on adults is difficult to interpret. In the first place, subjects evidently vary in their response to different levels of calcium in the diet. Positive balances for 12 days have been reported by Rose ('20) on a daily intake as low as 0.26 gm., by Kung and Yeh ('37) on 0.42, and by McLaughlin ('27) on 0.45 to 0.56, whereas negative balances have been found by Sherman and Winters ('18), Hunscher and co-workers ('34), and Ryder ('35) over periods of 16, 20, and 30 days on daily intakes of 0.08, 1.1, and 0.2 to 1.1 gm. respectively.

Also, there has been a difference in the proposed minimum requirement for physiological equilibrium. Sherman ('20, '37) has suggested 0.45 gm.; and other investigators (Brull, '36; Leitch, '37; Manoussakis, '24; and Steggerda and Mitchell, '39) have recommended amounts varying from 0.28 to 1.48 gm.

Balance studies have varied not only in their results but also in the methods used. Foremost, the length of the preliminary period for physiological adjustment to experimental diets and conditions has varied greatly. Some investigators (Bauer, Albright, and Aub, '29) have used one as short as 36 hours, while others have employed a 2-day period (Pyle and Huff, '36), a 3-day period (Padget et al., '33), a 5-day period (Manoussakis, '24), and a 10-day period (Bower et al., '32). The length of the metabolism or collecting period itself has varied. Many of the studies have been of brief duration, and

from single short periods--for example, those of Bogert and co-workers ('22). Even a "3-day balance period with a 24-hour sampling on the third day" has been considered by Pyle and Huff ('36) to merit "consideration as a clinical tool in determining human calcium and phosphorus utilization during pregnancy." The validity of conclusions drawn from short periods may be questioned, for other investigators such as Rose ('20) have found considerable variation in periods of similar length when the subjects have been on a constant diet. On the other hand, some have employed a series of short consecutive collection periods over intervals varying from 2 to 28 weeks (Rose, '20; Hunscher et al., '34; Kunerth and Pittman, '39; Pittman and Kunerth, '39; Ryder, '35; and Clark,'26). In studying the range or variation in retention of calcium and phosphorus in the normal child, Porter-Levin ('33) found that over a 90-day period on a constant mixed diet, furnishing 1 gm. each of calcium and phosphorus, 15 to 21 consecutive days were required to cover the entire range in retentions of the elements. The corresponding period for adults treated similarly has not been determined.

The kind of diet employed in the balance experiments has differed also. Because of the difficulty in preparing and analyzing the food composite, diets have been restricted usually to a few foods. The general self-chosen unrestricted mixed diet employed by Hunscher and co-workers ('34) has been the exception rather than the rule.

According to Ryder ('35) and Clark ('26), the calcium requirement for maintaining equilibrium in the human adult may depend not only upon the amount of the mineral needed for vital metabolic processes, but also upon the body stores of the mineral as determined by the previous diet over long periods. In Ryder's study, twenty 3-day collection periods on each of four healthy women at three levels of calcium intake (0.2, 0.4, and 1.1 gm. daily) showed negative balances at all levels. On the liberal allowance of 1.1 gm. of calcium daily, one subject, who had been on a low calcium intake before the experiment, attained practical equilibrium, whereas the other three subjects, who had been on a high calcium diet and exposed to much sunshine continued to show definite losses. In Clark's study the mineral metabolism of five men prisoners was ascertained over an interval divided into 28 weekly balances. The subjects were kept on a modified prison

diet furnishing about 0.7 gm. of calcium daily. As the data revealed, three subjects who had a history of limited food intake before the experiment stored 29.3, 38.3, and 52.7 gm. of calcium over 27, 28, and 27 weeks respectively; one of these had two slight negative balances, while the other two had only one. Of the two remaining subjects, one had a history of a diet liberal in dairy products and fresh vegetables and fruits; the other a diet consisting of moderate amounts. These two subjects stored only 3.5 and 11.3 gm. of calcium during 19 and 27 weeks respectively; one showed 7, the other 9, negative balances.

That the previous stores affect the retention of calcium has been substantiated further. Using rats as the test animals, Fairbanks and Mitchell ('36) found that "differences in the degree of saturation of the skeletal tissues with respect to calcium, brought about by previous subsistence upon diets differing in their contents of this element, produced inequalities in the retention of calcium under uniform conditions of calcium nutrition, such that low saturation is associated with subsequent high retention of calcium." This agrees with Daniels and co-workers ('35), who interpret high retentions of calcium in children as being due to previous depletion. Similarly, too, Wang et al. ('28), working with children, and Boldt, Brahm, and Andersen ('29), working with infants, suggest that the highly variable retentions of calcium reported for such subjects in the literature may be explained by the variable condition of their skeletal tissues with respect to calcium saturation.

Phosphorus-Balance Studies

The literature on the phosphorus balances of the human adult is not nearly so abundant as that on the calcium balances. Among the phosphorus balances studied there is variation in response to different levels in the diet. These variations are less marked than the calcium variations. On a daily intake of about 0.5 to 0.9 gm. Sherman and his co-workers ('18) found all balances to be negative; and Pittman ('32) on an intake of about 0.60 gm., and Hart ('28) on an intake of 0.85 gm. found all but one balance to be negative; on the other hand, Kramer and associates ('31) found all balances to be positive on an intake of 0.66 gm. Other investigators (Bower et al., '32; Burton, '30;

Hunscher et al., '34; Kramer et al., '28; Owen, '39; and Pittman and Kunerth, '39) found both positive and negative balances on daily intakes of about 0.36 to 1.90 gm.

Effect of Vitamin D on Calcium-Phosphorus Metabolism

Since the calcium-phosphorus metabolism of the normal adult is not yet clearly understood, naturally the effect of vitamin D on the metabolism of these elements in the adult is unknown. Because of the benefits derived by the child from a diet enhanced with vitamin D, adults have been encouraged to enrich their diets with this factor; but, it has yet to be proved that the normal adult, except the pregnant or lactating woman (Coons and Coons, '35; and Blunt and Cowan, '30), requires an additional source of vitamin D.[1]

Supplementing a low calcium diet (0.23-0.28 gm. daily) with irradiated rolled oats, Jaros ('28) noted no improvement in calcium and phosphorus retention in seven healthy women over a similar period when plain rolled oats were given. In an approximately 3-month balance study on a healthy male adult, living on a low calcium acidotic diet, Hart, Tourtellote, and Heyl ('28) found no increased tendency to calcium or phosphorus retention during the periods when the subject received daily irradiation or daily doses of cod-liver oil over a control period. Similar observations were made by Dye ('30) on a group of women consuming a low calcium diet. The conclusions were drawn, however, from single balances made before and after a 38-day period of cod liver oil administration and an 11-week period of irradiation. No special advantages in the utilization of calcium and phosphorus of milk in a group of five women irradiated daily for 5 minutes during an 18-day period over a group of five others receiving no irradiation have been observed by Kramer and associates ('31). In an experiment by Hunscher and co-workers ('34) three healthy women showed no consistent physiological changes in the retention of calcium or phosphorus due to cod-liver oil during 38 continuous experimental days of their usual unrestricted diet and their

---

[1] In the study by Coons, a daily dose of 15 gm. of Mead's Standardized Cod-liver Oil, purchased in the open market, caused only slight and irregular improvement in calcium and phosphorus retention in the pregnant woman.

customary activities. A study of urinary calcium excretion in two women patients by Buttner ('39) indicated no alteration in the average rate of excretion in either subject during a 6-day control period and a subsequent 14-day period when cod-liver oil was added to the diet. Among a group of robust men who had a low blood-phosphorus level in the winter months, Havard and Hoyle ('28) failed to note any effect upon the blood phosphorus level during the low period after 21 days of irradiated ergosterol administration or after 16 days of ultra-violet light irradiation. In contrast, similar treatment of children, showing the same low blood-phosphorus, increased the amount of this element. In studying the effect of irradiated ergosterol when administered in daily doses varying from 8,000 to 32,000 U.S.P. vitamin D units on the calcium and phosphorus balance and the level of these elements in the blood of two normal adults, Bauer, Marble, and Caflin ('32) noted no constant changes whether the diet was high or low in calcium.

EXPERIMENTAL PROCEDURE

Because previous work on the problem of calcium and phosphorus metabolism in the adult has been confined to rather short periods of time employing, usually, restricted or special experimental diets, this investigation was designed to cover a long period and to employ a general mixed diet meeting all nutritional requirements.

Subjects.--Seven university women aged twenty to twenty-seven served as subjects. They were in good health as judged by their heights and weights, medical histories, basal metabolic rates, and general appearance. Their customary life was modified as little as possible. They continued to live in their respective dwellings and to engage in their usual academic, social, and physical activities. The only departure from their normal lives was the consumption of their meals in the nutrition laboratory, the collection of their excreta, and the withdrawal of blood samples every two or three weeks.

Diets.--The diet was planned to meet the usual standards for calories, protein, minerals, and vitamins; to approximate a general mixed diet; to provide a constant intake; to include a pint of milk daily per subject; to satisfy the individual food

likes; and to offer enough variety to promote contentment over a long time. The foods included in each 5-day period are given in Table 1. Under "foundation" diet are listed the kind and amounts of foods consumed each 5-day period by each subject; and under "ad libitum" appear other foods, chosen for palatability and for low mineral content, which were freely permitted in order that the subjects might satisfy their individual energy requirements. To insure fairly uniform composition, most foods were purchased from the same source, and the canned goods in case lots. Monotony was avoided by varying the order, combination, and methods of preparation.

TABLE 1

INDIVIDUAL DIETARY FOR EACH FIVE-DAY PERIOD

Foods Foundation Diet	Amount in Grams	Foods Ad Libitum
Orange juice.....	200	White bread
Orange ice.....	100	Butter
Tomato juice.....	200	Jelly
Tomato soup concentrate	70	Apples
Grapefruit.....	100	Salad dressing
Peaches, canned.....	80	Jello
Pineapple, canned.....	80	Plain cookies
Banana.....	100	Candy
String beans, canned...	70	Coffee
Beets, canned.....	70	Tea
Cabbage.....	100	Distilled water
Carrots.....	100	
Lettuce.....	50	
Onions.....	60	
Peas, canned.....	70	
Potatoes, white.....	200-400	
Potatoes, canned sweet.	100	
Whole wheat bread.....	300	
Doughnuts.....	60	
Bacon.....	20	
Beef, lean.....	400	
Salmon.....	90	
Eggs, whole.....	150	
Milk.....	2,400	

All subjects received the same basal diet. Subjects I,[1]

[1]During periods N through P, subject I, who was also serving as a subject for an iron metabolism study, received daily 5.14 mg. of ferric ammonium citrate.

II, and V[1] served as controls; subjects III and IV had, besides the basal diet, a 4.8-gm. daily dose of cod-liver oil supplying 945 U.S.P. units of vitamin D (equivalent to one tablespoon of standard cod-liver oil); and subjects V,[2] VI, and VII drank irradiated milk furnishing 67.5 U.S.P. units of vitamin D in place of the plain pasteurized milk taken by the other subjects.

Experimental period.--The experiment was in progress from January 2 until May 22. Collections were started after the subjects had been on the experimental diet for a preliminary period of 10 days. Twenty-six continuous 5-day collection periods (A through Z) were run on subjects I, III, and VI; twenty continuous 5-day periods (A through T) on subjects II, IV, and VII, and fifteen nonconsecutive 5-day periods (C through E and I through T) on subject V.

Blood calcium and phosphorus.--About 10 cc. of venous blood was drawn before breakfast from each of six of the subjects[3] on the first or second day of the menstrual period and again approximately midway in the menstrual cycle.

Records.--Records were made of the daily hours of sleep, unusual or strenuous exercise, emotional disturbances, physiological upsets, previous dietary habits, food and liquid consumption, and weight.[4]

Analytical methods.--The generally accepted procedure for metabolic balances was employed. For the analytical determina-

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[1]Although subject V received the experimental diet along with the other six subjects, the research was not originally planned to include her as a subject. As the experiment progressed it was decided to run a few balance periods (C through E) on her to establish a norm in the event that she might have to substitute for one of the other subjects. When, at the beginning of period I, a subject in the irradiated milk group developed constipation, subject V was added to this group.

[2]See n. 1.

[3]A blood sample was somewhat difficult to withdraw from subject VII, because her arm veins were deeply imbedded in subcutaneous tissue. This procedure was therefore omitted in her case in order to avoid the risk of upsetting her emotionally.

[4]Weights were recorded at the beginning of each 5-day period and on the day following the close of the experiment. The subjects were weighed nude before breakfast after the bladder had been emptied.

tions of the food and excreta for each subject per period, one-tenth of the weighed food intakes, one-fifth of the urine, and all of the feces were made into composite samples. Food, feces, and urine were ashed according to the wet ashing method of Stearns ('29). Calcium was precipitated as calcium oxalate by the McCrudden method ('11-'12) at a pH of 5, as Shohl ('22) recommends, with brom cresol green as the indicator. Phosphorus was determined by Fiske and Subbarow's ('25) colorimetric method, blood phosphorus by their method ('25), and blood calcium by Clark and Collip's modification of the Kramer and Tisdall ('25) method.

RESULTS AND DISCUSSION

General Health and Fecal Eliminations of the Subjects

The subjects maintained their health, weight, and spirits throughout the experiment. Subject VII soon became constipated and remained so the entire time. This was her only apparent abnormality. When it became evident that the intestinal motility of this subject was unusually slow, subject V was added to her group.

The individual variation in intestinal motility between these normal subjects may be seen in Figure 1, representing the number of days required for the carmine given at the beginning of each period to appear in the feces. For subject III, IV, V, and VI the carmine almost always appeared within 24 hours. In subjects I and II the intestinal motility was irregular--usually two or three times as slow as the subjects previously mentioned. In subject VII it was extremely sluggish, the carmine remaining in the intestine anywhere from 2 to 10 days, with an average of 7 days.[1]

Figure 2 shows the number of stools passed by each subject, from the appearance in the feces of the carmine given at the beginning of a period to the appearance of that given at the beginning of the following period. Again there is variation from subject to subject.

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[1]To be assured of no mistake in identifying the carmine in the feces of this subject, glass beads were given along with the carmine several times throughout the experiment.

The stools were also characteristic. Those of subject I were well-formed and large; those of subject II were somewhat dry but formed; those of subjects III and VI were moist and not always well formed; those of IV and V were well-formed and moderately large; and those of subject VII were usually small, dry, hard, and ball-shaped although occasionally moist and well-formed.

Calcium Analysis of Food and Excreta

The calcium and phosphorus analyses of the food and excreta are given in Table 2 and expressed as daily averages in grams. Analysis of the data appears in Table 3; graphic representation in Figures 3 and 4.

Calcium intake.--As the experiment was planned, the calcium content of the diet was to be kept fairly constant. When compared, the average daily calcium intakes of the subjects for the entire experiment appear quite similar: 0.820, 0.742, 0.694, 0.689, 0.756, 0.748, 0.739, and 0.697 gm. The maximum variation between these averages is no more than 0.131 gm. On the per-kilogram-of-body-weight basis the intakes are also similar: 0.014, 0.012, 0.013, 0.015, 0.014, 0.014, 0.014, and 0.011 gm. The difference between the largest and smallest is 0.004 gm.--no more than the larger individual variation from period to period. If, on the other hand, the average daily intakes for the individual 5-day periods are compared, there are variations from period to period. If the one exceptionally high intake recorded for subject III in period A is disregarded, the intakes fluctuate only 0.1 to 0.2 gm. on either side of the liberal allowance of 0.68 gm. recommended by Sherman ('37). The coefficients of variation further indicate the calcium intakes to be fairly constant. One was approximately 18, and the remainder about 10 or less. Certainly the variation is no more than in the calcium intake of a normal, healthy adult on a self-chosen mixed diet, as is shown when these calcium intakes are compared with the self-chosen diets of Hunscher and co-worker's ('34) subjects.

Calcium output.--The urinary calcium excretions, both total and per kilogram of body weight, indicate an individual consistency but a variation between the subjects; this corroborates Ryder's ('35) findings. Apparently the proportion of the total calcium excreted in the urine is not affected by vitamin D,

Figure 1

This chart illustrates the variation in gastric motility between the subjects. The vertical bars represent the number of days required for the carmine given at the beginning of each period to appear in the feces. Subjects I and II are the control group; subjects III and IV the cod liver oil group; and subjects V, VI, and VII the irradiated milk group.

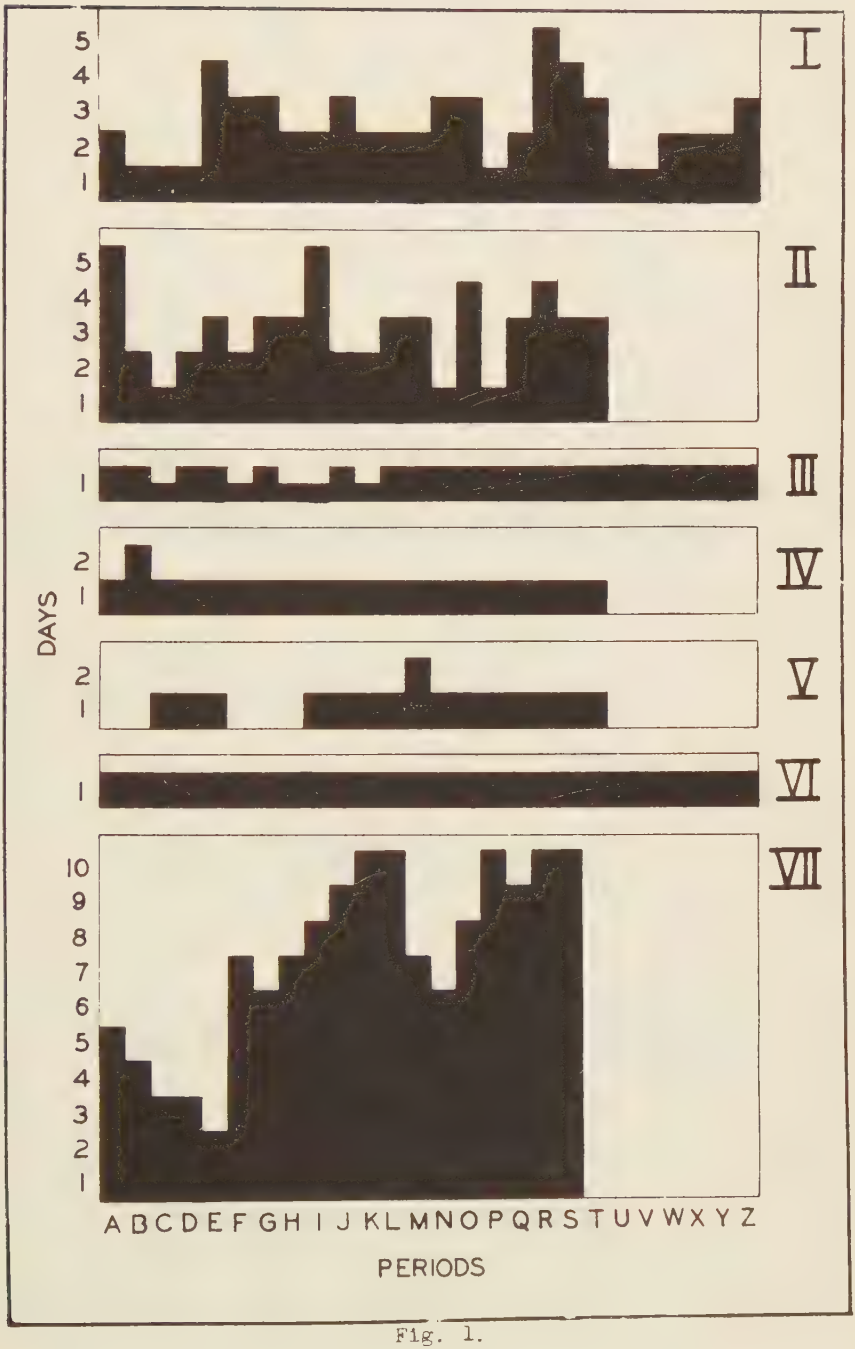
I
II
III
IV
V
VI
VII
DAYS
5
4
3
2
1
10
9
8
7
6
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
PERIODS

Fig. 1.

Figure 2

This chart represents the number of stools passed by each subject from the appearance in the feces of the carmine given at the beginning of the period to the appearance of that given at the beginning of the following period. Subjects I and II are the control group; subjects III and IV are the cod liver oil group; and subjects V, VI, and VII the irradiated milk group.

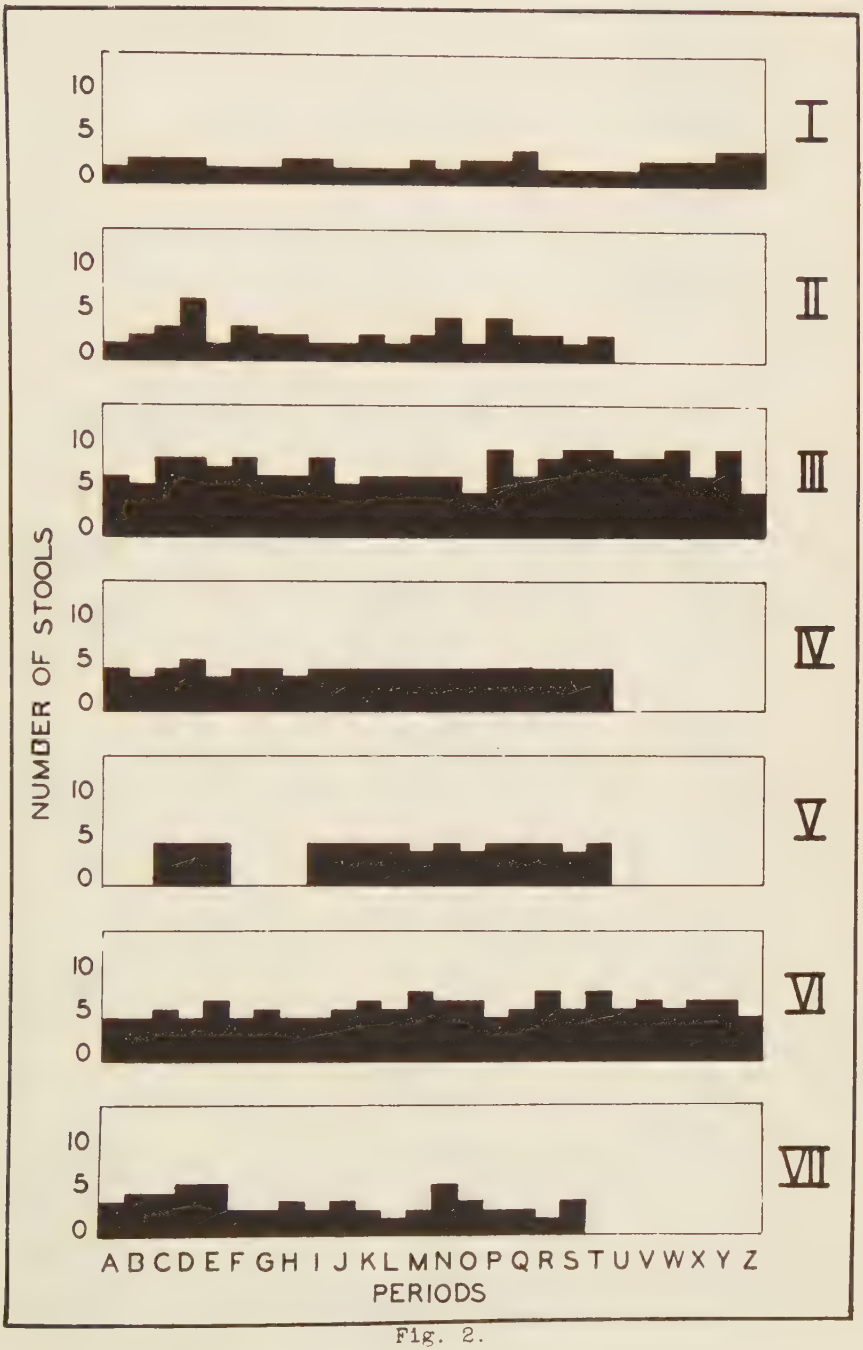
NUMBER OF STOOLS
10
5
0
I
II
III
IV
V
VI
VII
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
PERIODS

Fig. 2.

Figure 3

This chart gives a graphic presentation of the calcium balances for each subject. The horizontal line represents equilibrium. All vertical bars above this line indicate the number of grams the subject is in positive balance; all vertical bars below the line the number of grams the subject is in negative balance.

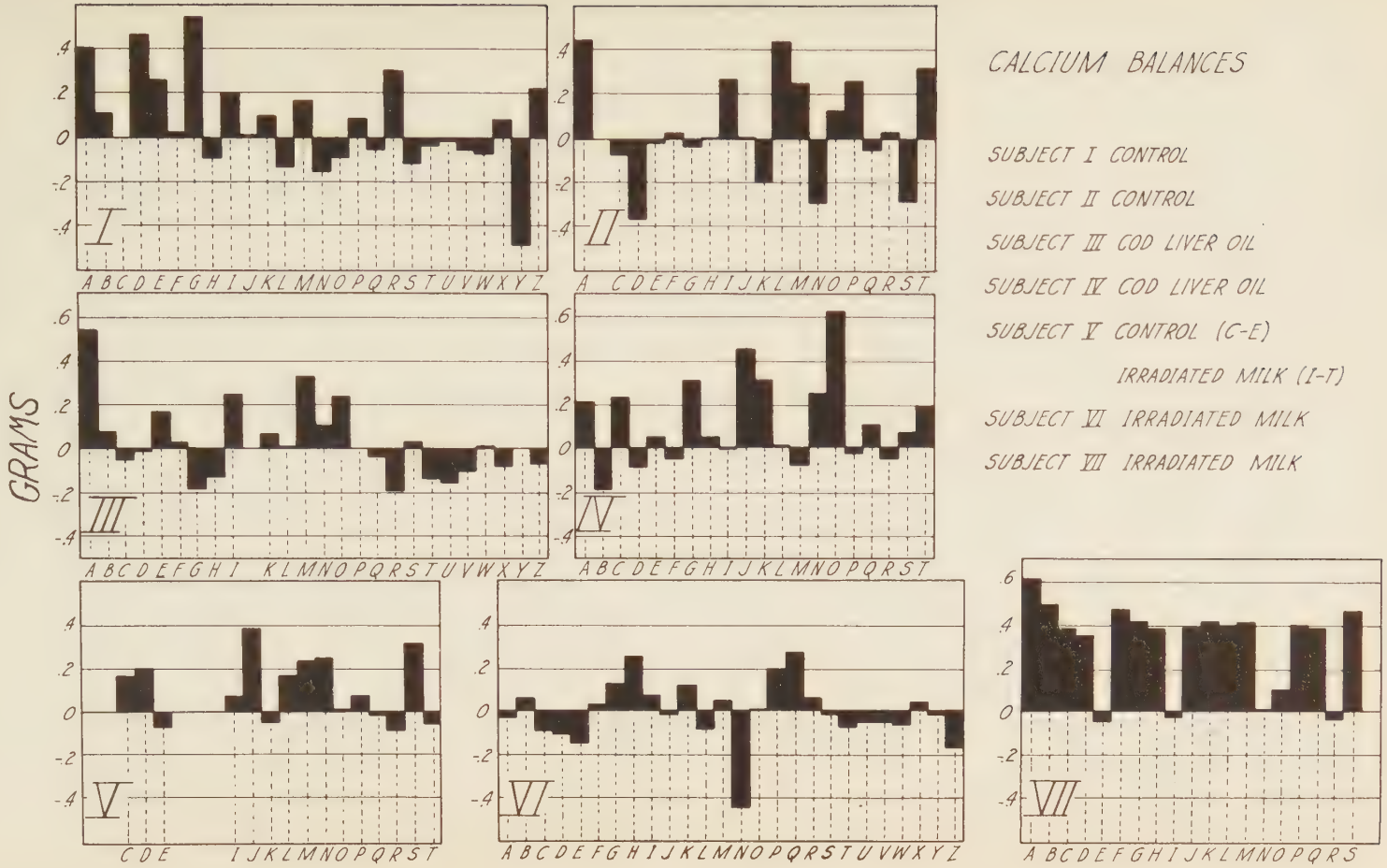
CALCIUM BALANCES
SUBJECT I CONTROL
SUBJECT II CONTROL
SUBJECT III COD LIVER OIL
SUBJECT IV COD LIVER OIL
SUBJECT V CONTROL (C-E)
IRRADIATED MILK (I-T)
SUBJECT VI IRRADIATED MILK
SUBJECT VII IRRADIATED MILK
GRAMS
I
II
III
IV
V
VI
VII

Fig. 3

Figure 4

This chart gives a graphic presentation of the phosphorus balances for each subject. The horizontal line represents equilibrium. All vertical bars above this line indicate the number of grams the subject is in positive balance; all vertical bars below the line the number of grams the subject is in negative balance.

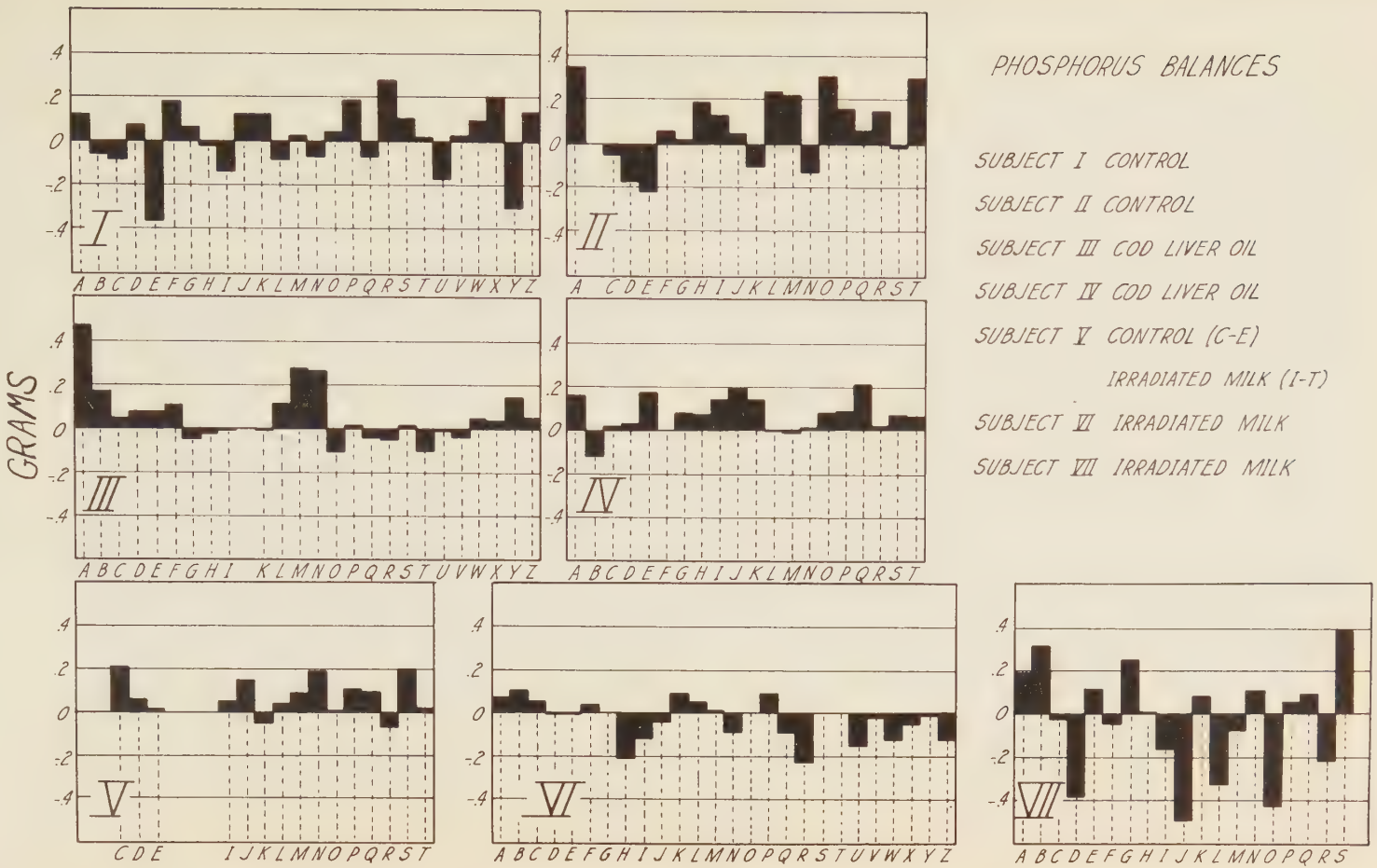
PHOSPHORUS BALANCES
SUBJECT I CONTROL
SUBJECT II CONTROL
SUBJECT III COD LIVER OIL
SUBJECT IV COD LIVER OIL
SUBJECT V CONTROL (C-E)
IRRADIATED MILK (I-T)
SUBJECT VI IRRADIATED MILK
SUBJECT VII IRRADIATED MILK
GRAMS
.4
.2
0
-.2
-.4
I
II
III
IV
V
VI
VII
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Fig. 4 -

TABLE 2

SUMMARY OF CALCIUM AND PHOSPHORUS DATA

Daily Average in Grams

Subject I (Control)

Period	CALCIUM									PHOSPHORUS								
	Intake		Output						Balance	Intake		Output						Balance
			Urine		Feces		Total					Urine		Feces		Total		
	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.		Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	
A	0.808	0.014	0.133	0.002	0.265	0.005	0.398	0.007	+0.410	1.076	0.018	0.616	0.010	0.340	0.006	0.956	0.016	+0.120
B	0.803	0.014	0.183	0.003	0.509	0.009	0.692	0.012	+0.111	1.016	0.017	0.544	0.009	0.533	0.009	1.077	0.018	-0.061
C	0.700	0.012	0.172	0.003	0.528	0.009	0.700	0.012	0.000	1.164	0.020	0.762	0.013	0.490	0.008	1.252	0.021	-0.088
D	0.840	0.014	0.168	0.003	0.205	0.003	0.373	0.006	+0.467	1.286	0.022	0.614	0.010	0.593	0.010	1.207	0.020	+0.079
E	0.737	0.012	0.196	0.003	0.280	0.005	0.476	0.008	+0.261	1.076	0.018	0.747	0.013	0.688	0.012	1.435	0.025	-0.359
F	0.831	0.014	0.201	0.003	0.606	0.010	0.807	0.013	+0.024	1.258	0.021	0.661	0.011	0.406	0.007	1.067	0.018	+0.191
G	0.947	0.016	0.177	0.003	0.224	0.004	0.401	0.007	+0.546	1.310	0.020	0.777	0.013	0.459	0.008	1.236	0.021	+0.074
H	0.792	0.013	0.220	0.004	0.668	0.011	0.888	0.015	-0.096	1.248	0.021	0.811	0.014	0.453	0.008	1.264	0.022	-0.016
I	0.871	0.015	0.224	0.004	0.438	0.007	0.662	0.011	+0.209	1.286	0.022	0.850	0.014	0.574	0.010	1.424	0.024	-0.138
J	0.836	0.014	0.231	0.004	0.595	0.010	0.826	0.014	+0.010	1.313	0.022	0.767	0.013	0.410	0.007	1.177	0.020	+0.136
K	0.963	0.016	0.242	0.004	0.615	0.010	0.857	0.014	+0.106	1.324	0.022	0.782	0.013	0.411	0.007	1.193	0.020	+0.131
L	0.827	0.014	0.206	0.003	0.756	0.013	0.962	0.016	-0.135	1.196	0.020	0.839	0.014	0.443	0.008	1.282	0.022	-0.086
M	0.799	0.014	0.184	0.003	0.438	0.007	0.622	0.010	+0.177	1.159	0.020	0.744	0.013	0.384	0.006	1.128	0.019	+0.031
N	0.966	0.016	0.188	0.003	0.931	0.016	1.119	0.019	-0.153	1.344	0.023	0.698	0.012	0.721	0.012	1.419	0.024	-0.075
O	0.800	0.014	0.237	0.004	0.655	0.011	0.892	0.015	-0.092	1.280	0.022	0.614	0.010	0.619	0.010	1.233	0.020	+0.047
P	0.950	0.016	0.205	0.003	0.647	0.011	0.852	0.014	+0.098	1.362	0.023	0.723	0.012	0.449	0.008	1.172	0.020	+0.190
Q	0.610	0.010	0.197	0.003	0.465	0.008	0.662	0.011	-0.052	1.264	0.021	0.889	0.015	0.443	0.008	1.332	0.023	-0.068
R	0.863	0.015	0.185	0.003	0.337	0.006	0.552	0.009	+0.311	1.255	0.021	0.690	0.012	0.284	0.005	0.974	0.017	+0.281
S	0.646	0.011	0.229	0.004	0.535	0.009	0.764	0.013	-0.118	1.316	0.022	0.781	0.013	0.427	0.007	1.208	0.020	+0.108
T	0.852	0.014	0.227	0.004	0.655	0.011	0.882	0.015	-0.030	1.252	0.021	0.784	0.013	0.449	0.008	1.233	0.021	+0.019
U	0.808	0.014	0.213	0.004	0.607	0.010	0.820	0.014	-0.012	1.093	0.019	0.720	0.012	0.549	0.009	1.269	0.021	-0.176
V	0.808	0.014	0.203	0.003	0.663	0.011	0.866	0.014	-0.058	1.320	0.022	0.753	0.013	0.533	0.009	1.286	0.022	+0.034
W	0.832	0.014	0.235	0.004	0.667	0.011	0.902	0.015	-0.070	1.369	0.023	0.810	0.014	0.459	0.008	1.269	0.022	+0.100
X	0.757	0.013	0.211	0.004	0.455	0.008	0.666	0.012	+0.091	1.180	0.020	0.692	0.012	0.279	0.005	0.971	0.017	+0.209
Y	0.789	0.013	0.129	0.002	1.140	0.019	1.269	0.021	-0.480	1.320	0.022	0.810	0.014	0.810	0.014	1.620	0.028	-0.300
Z	0.895	0.015	0.170	0.003	0.491	0.008	0.661	0.011	+0.234	1.293	0.022	0.810	0.014	0.340	0.006	1.150	0.020	+0.143
T.	21.330		5.166		14.375		19.541		+1.789	32.360		19.288		12.546		31.834		+0.526
Av.	0.820	0.014	0.199	0.003	0.553	0.009	0.752	0.013	+0.069	1.245	0.021	0.742	0.013	0.483	0.008	1.224	0.021	+0.020

TABLE 2--Continued

Daily Average in Grams
Subject II (Control)

Period	CALCIUM									PHOSPHORUS								
	Intake		Output						Balance	Intake		Output						Balance
			Urine		Feces		Total					Urine		Feces		Total		
	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.		Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	
A	0.753	0.012	0.146	0.002	0.150	0.002	0.296	0.004	+0.457	1.076	0.018	0.589	0.010	0.132	0.002	0.721	0.012	+0.355
B	0.711	0.012	0.170	0.003	.....	.....	.....	.....	.....	1.039	0.017	0.586	0.010	.....	.....	.....	.....	.....
C	0.799	0.013	0.157	0.003	0.718	0.012	0.875	0.015	-0.076	1.361	0.022	0.710	0.012	0.702	0.012	1.412	0.024	-0.051
D	0.670	0.011	0.170	0.003	0.867	0.014	1.037	0.017	-0.367	1.180	0.019	0.718	0.012	0.634	0.010	1.352	0.022	-0.172
E	0.694	0.011	0.159	0.003	0.547	0.009	0.706	0.012	-0.012	1.024	0.017	0.809	0.013	0.434	0.007	1.243	0.020	-0.219
F	0.638	0.010	0.168	0.003	0.433	0.007	0.601	0.010	+0.037	1.191	0.020	0.675	0.011	0.450	0.007	1.125	0.018	+0.066
G	0.759	0.012	0.178	0.003	0.618	0.010	0.796	0.013	-0.037	1.153	0.019	0.697	0.011	0.433	0.007	1.130	0.018	+0.023
H	0.820	0.013	0.202	0.003	0.608	0.010	0.810	0.013	+0.010	1.249	0.020	0.640	0.010	0.420	0.007	1.060	0.017	+0.189
I	0.717	0.012	0.184	0.003	0.255	0.004	0.439	0.007	+0.278	1.258	0.021	0.693	0.011	0.435	0.007	1.128	0.018	+0.130
J	0.800	0.013	0.193	0.003	0.603	0.010	0.796	0.013	+0.004	1.228	0.020	0.762	0.012	0.410	0.007	1.172	0.019	+0.056
K	0.796	0.013	0.156	0.003	0.832	0.014	0.988	0.017	-0.192	1.208	0.020	0.701	0.011	0.611	0.010	1.312	0.021	-0.104
L	0.840	0.014	0.170	0.003	0.228	0.004	0.398	0.007	+0.442	1.297	0.021	0.695	0.011	0.358	0.006	1.053	0.017	+0.244
M	0.686	0.011	0.189	0.003	0.239	0.004	0.428	0.007	+0.258	1.225	0.020	0.659	0.011	0.346	0.006	1.005	0.016	+0.220
N	0.646	0.011	0.197	0.003	0.739	0.012	0.936	0.015	-0.290	1.123	0.019	0.717	0.012	0.533	0.009	1.250	0.020	-0.127
O	0.663	0.011	0.161	0.003	0.374	0.006	0.535	0.009	+0.128	1.193	0.020	0.599	0.010	0.280	0.005	0.879	0.015	+0.314
P	0.757	0.012	0.189	0.003	0.306	0.005	0.495	0.008	+0.262	1.274	0.021	0.667	0.011	0.445	0.007	1.112	0.018	+0.162
Q	0.710	0.012	0.182	0.003	0.579	0.010	0.761	0.013	-0.051	1.297	0.021	0.800	0.013	0.431	0.007	1.231	0.020	+0.066
R	0.734	0.012	0.122	0.002	0.580	0.010	0.702	0.012	+0.032	1.255	0.021	0.681	0.011	0.419	0.007	1.100	0.018	+0.155
S	0.836	0.014	0.167	0.003	0.952	0.016	1.119	0.019	-0.283	1.407	0.023	0.700	0.011	0.727	0.012	1.427	0.023	-0.020
T	0.804	0.013	0.129	0.002	0.354	0.006	0.483	0.006	+0.321	1.316	0.022	0.650	0.011	0.369	0.006	1.019	0.017	+0.297
T.	14.833		3.389		9.982		13.201		+0.921	24.354		13.748		8.569		21.731		+1.584
Av.	0.742	0.012	0.170	0.003	0.525	0.009	0.695	0.011	+0.048	1.218	0.020	0.687	0.011	0.451	0.007	1.144	0.019	+0.083

TABLE 2--Continued

Daily Average in Grams
Subject III (Cod Liver Oil)

Period	CALCIUM									PHOSPHORUS								
	Intake		Output						Bal-ance	Intake		Output						Bal-ance
			Urine		Feces		Total					Urine		Feces		Total		
	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.		Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	
A	1.206	0.027	0.193	0.004	0.473	0.010	0.666	0.014	+0.540	1.454	0.032	0.618	0.014	0.368	0.008	0.986	0.022	+0.468
B	0.533[a]	0.012	0.131	0.003	0.266	0.006	0.397	0.009	+0.136	1.026	0.023	0.542	0.012	0.312	0.007	0.854	0.019	+0.172
C	0.715	0.016	0.193	0.004	0.576	0.013	0.769	0.017	-0.054	1.118	0.025	0.657	0.014	0.411	0.009	1.068	0.023	+0.050
D	0.662	0.015	0.216	0.005	0.456	0.010	0.672	0.015	-0.010	1.076	0.024	0.624	0.014	0.370	0.008	0.994	0.022	+0.082
E	0.631	0.014	0.235	0.005	0.224	0.005	0.459	0.010	+0.172	1.082	0.024	0.600	0.013	0.395	0.009	0.995	0.022	+0.087
F	0.788	0.017	0.226	0.005	0.536	0.012	0.762	0.017	+0.026	1.123	0.025	0.636	0.014	0.377	0.008	1.013	0.022	+0.110
G	0.593	0.013	0.225	0.005	0.553	0.012	0.778	0.017	-0.185	1.071	0.024	0.665	0.015	0.453	0.010	1.118	0.025	-0.047
H	0.580	0.013	0.222	0.005	0.486	0.011	0.708	0.016	-0.128	0.959	0.021	0.600	0.013	0.386	0.009	0.986	0.022	-0.027
I	0.733	0.016	0.209	0.005	0.270	0.006	0.479	0.011	+0.254	1.045	0.023	0.638	0.014	0.414	0.009	1.052	0.023	-0.007
J	.....	.....	0.228	0.005	0.508	0.011	0.736	0.016	.....	.....	.....	0.645	0.014	0.365	0.008	1.010	0.022	.....
K	0.702	0.016	0.243	0.005	0.390	0.009	0.633	0.014	+0.069	1.053	0.023	0.703	0.016	0.357	0.008	1.060	0.024	-0.007
L	0.678	0.015	0.165	0.004	0.523	0.012	0.688	0.016	-0.010	1.148	0.025	0.669	0.015	0.363	0.008	1.032	0.023	+0.116
M	0.765	0.017	0.211	0.005	0.221	0.005	0.432	0.010	+0.333	1.391	0.031	0.686	0.015	0.423	0.009	1.109	0.024	+0.282
N	0.741	0.016	0.215	0.005	0.422	0.009	0.637	0.014	+0.104	1.407	0.031	0.673	0.015	0.465	0.010	1.138	0.025	+0.269
O	0.772	0.017	0.184	0.004	0.348	0.008	0.532	0.012	+0.240	1.049	0.023	0.640	0.014	0.517	0.011	1.157	0.025	-0.108
P	0.599	0.013	0.223	0.005	0.379	0.008	0.602	0.013	-0.003	1.110	0.025	0.643	0.014	0.439	0.010	1.082	0.024	+0.028
Q	0.670	0.015	0.244	0.005	0.468	0.010	0.712	0.015	-0.042	1.094	0.024	0.703	0.016	0.434	0.010	1.137	0.026	-0.043
R	0.654	0.014	0.263	0.006	0.583	0.013	0.846	0.019	-0.192	1.027	0.023	0.682	0.015	0.397	0.009	1.079	0.024	-0.052
S	0.631	0.014	0.269	0.006	0.325	0.007	0.594	0.013	+0.037	1.113	0.025	0.648	0.014	0.445	0.010	1.093	0.024	+0.020
T	0.622	0.014	0.245	0.005	0.521	0.012	0.766	0.017	-0.144	1.027	0.023	0.692	0.015	0.444	0.010	1.136	0.025	-0.109
U	0.646	0.014	0.218	0.005	0.587	0.013	0.805	0.018	-0.159	1.167	0.026	0.763	0.017	0.414	0.009	1.177	0.026	-0.010
V	0.679	0.015	0.187	0.004	0.596	0.013	0.783	0.017	-0.104	1.138	0.025	0.688	0.015	0.493	0.011	1.181	0.026	-0.043
W	0.663	0.015	0.182	0.004	0.472	0.010	0.654	0.014	+0.009	1.136	0.025	0.696	0.015	0.387	0.009	1.083	0.024	+0.053
X	0.674	0.015	0.186	0.004	0.570	0.013	0.756	0.017	-0.082	1.073	0.024	0.621	0.014	0.411	0.009	1.032	0.023	+0.041
Y	0.662	0.015	0.196	0.004	0.468	0.010	0.664	0.014	-0.002	1.067	0.024	0.576	0.013	0.336	0.007	0.912	0.020	+0.155
Z	0.631	0.014	0.262	0.006	0.442	0.010	0.704	0.016	-0.073	1.129	0.025	0.688	0.015	0.391	0.009	1.079	0.024	+0.050
T.	17.230		5.571		11.663		17.234		+0.732	28.083		16.996		10.567		27.563		+1.530
Av.	0.689	0.015	0.214	0.005	0.449	0.010	0.663	0.015	+0.029	1.123	0.025	0.654	0.015	0.406	0.009	1.060	0.024	+0.061

[a]The total amount of milk provided in the diet failed to be consumed during this period.

Table 2--Continued

Daily Average in Grams
Subject IV (Cod Liver Oil)

Period	CALCIUM									PHOSPHORUS								
	Intake		Output						Balance	Intake		Output						Balance
			Urine		Feces		Total					Urine		Feces		Total		
	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.		Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	
A	0.867	0.016	0.076	0.001	0.580	0.010	0.656	0.011	+0.211	1.177	0.022	0.604	0.011	0.412	0.008	1.016	0.019	+0.161
B	0.820	0.015	0.078	0.001	0.931	0.017	1.009	0.018	-0.189	1.116	0.021	0.692	0.013	0.542	0.010	1.234	0.023	-0.118
C	0.741	0.014	0.090	0.002	0.414	0.008	0.504	0.010	+0.237	1.113	0.021	0.720	0.013	0.369	0.007	1.089	0.020	+0.024
D	0.504	0.009	0.099	0.002	0.496	0.009	0.595	0.011	-0.091	1.164	0.022	0.683	0.013	0.453	0.008	1.136	0.021	+0.028
E	0.725	0.013	0.093	0.002	0.582	0.011	0.675	0.013	+0.050	1.078	0.020	0.581	0.011	0.325	0.006	0.906	0.017	+0.172
F	0.733	0.014	0.085	0.002	0.701	0.013	0.786	0.015	-0.053	1.099	0.020	0.687	0.013	0.412	0.008	1.099	0.021	-0.000
G	0.725	0.013	0.082	0.002	0.326	0.006	0.408	0.008	+0.317	1.096	0.020	0.605	0.011	0.410	0.008	1.015	0.019	+0.081
H	0.825	0.015	0.105	0.002	0.672	0.012	0.777	0.014	+0.048	1.138	0.021	0.682	0.013	0.378	0.007	1.060	0.020	+0.078
I	0.786	0.015	0.082	0.002	0.706	0.013	0.788	0.015	-0.002	1.202	0.022	0.648	0.012	0.417	0.008	1.065	0.020	+0.137
J	0.741	0.014	0.115	0.002	0.171	0.003	0.286	0.005	+0.455	1.225	0.023	0.657	0.012	0.378	0.007	1.035	0.019	+0.190
K	0.828	0.015	0.105	0.002	0.411	0.008	0.516	0.010	+0.312	1.309	0.024	0.732	0.014	0.436	0.008	1.168	0.022	+0.141
L	0.828	0.015	0.094	0.002	0.720	0.013	0.814	0.015	+0.014	1.172	0.022	0.723	0.013	0.453	0.008	1.176	0.021	-0.004
M	0.672	0.012	0.127	0.002	0.628	0.012	0.755	0.014	-0.083	1.156	0.021	0.704	0.013	0.469	0.009	1.173	0.022	-0.017
N	0.800	0.015	0.118	0.002	0.432	0.008	0.550	0.010	+0.250	1.071	0.020	0.648	0.012	0.405	0.007	1.053	0.019	+0.018
O	0.820	0.015	0.126	0.002	0.070	0.001	0.196	0.003	+0.624	1.130	0.021	0.633	0.012	0.401	0.007	1.034	0.019	+0.096
P	0.757	0.014	0.108	0.002	0.674	0.012	0.782	0.014	-0.025	1.174	0.022	0.680	0.013	0.397	0.007	1.077	0.020	+0.097
Q	0.733	0.014	0.095	0.002	0.531	0.010	0.626	0.012	+0.107	1.255	0.023	0.718	0.013	0.330	0.006	1.048	0.019	+0.207
R	0.717	0.013	0.103	0.002	0.663	0.012	0.766	0.014	-0.049	1.237	0.023	0.681	0.013	0.535	0.010	1.216	0.023	+0.021
S	0.743	0.014	0.111	0.002	0.553	0.010	0.664	0.012	+0.079	1.237	0.023	0.711	0.013	0.451	0.008	1.162	0.021	+0.075
T	0.755	0.014	0.115	0.002	0.441	0.008	0.556	0.010	+0.199	1.174	0.022	0.727	0.013	0.387	0.007	1.114	0.020	+0.060
T.	15.120		2.007		10.702		12.709		+2.411	23.323		13.516		8.360		21.876		+1.447
Av.	0.756	0.014	0.100	0.002	0.535	0.010	0.635	0.012	+0.121	1.166	0.022	0.676	0.013	0.418	0.008	1.094	0.020	+0.072

TABLE 2--Continued

Daily Average in Grams
Subject V (Control)

Period	CALCIUM									PHOSPHORUS								
	Intake		Output						Balance	Intake		Output						Balance
			Urine		Feces		Total					Urine		Feces		Total		
	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.		Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	
C	0.694	0.013	0.130	0.003	0.402	0.008	0.532	0.011	+0.162	1.191	0.023	0.577	0.011	0.401	0.008	0.978	0.019	+0.213
D	0.709	0.014	0.170	0.003	0.339	0.007	0.509	0.010	+0.200	1.053	0.020	0.698	0.013	0.291	0.006	0.989	0.019	+0.064
E	0.680	0.013	0.171	0.003	0.580	0.011	0.751	0.014	-0.071	1.113	0.021	0.616	0.012	0.479	0.009	1.095	0.021	+0.018
T.	2.083		0.471		1.321		1.792		+0.291	3.357		1.891		1.171		3.062		+0.295
Av.	0.694	0.013	0.157	0.003	0.440	0.009	0.597	0.011	+0.097	1.119	0.022	0.630	0.012	0.390	0.008	1.021	0.020	+0.098
	(Irradiated Milk)																	
I	0.762	0.015	0.148	0.003	0.536	0.010	0.684	0.013	+0.078	1.174	0.023	0.691	0.013	0.431	0.008	1.122	0.021	+0.052
J	0.840	0.016	0.143	0.003	0.317	0.006	0.460	0.009	+0.380	1.347	0.026	0.709	0.014	0.490	0.009	1.199	0.023	+0.148
K	0.674	0.013	0.151	0.003	0.574	0.011	0.725	0.014	-0.051	1.138	0.022	0.727	0.014	0.466	0.009	1.193	0.023	-0.055
L	0.702	0.013	0.152	0.003	0.385	0.007	0.537	0.010	+0.165	1.202	0.023	0.711	0.014	0.449	0.009	1.160	0.023	+0.042
M	0.757	0.015	0.162	0.003	0.361	0.007	0.523	0.010	+0.234	1.177	0.023	0.648	0.012	0.436	0.008	1.084	0.020	+0.093
N	0.832	0.016	0.170	0.003	0.419	0.008	0.589	0.011	+0.243	1.219	0.023	0.634	0.012	0.394	0.008	1.028	0.020	+0.191
O	0.702	0.013	0.148	0.003	0.549	0.011	0.697	0.014	+0.005	1.123	0.022	0.647	0.012	0.457	0.009	1.104	0.021	+0.019
P	0.662	0.013	0.165	0.003	0.425	0.008	0.590	0.011	+0.072	1.166	0.022	0.658	0.013	0.395	0.008	1.053	0.021	+0.113
Q	0.769	0.015	0.154	0.003	0.635	0.012	0.789	0.015	-0.020	1.286	0.025	0.750	0.014	0.439	0.008	1.189	0.022	+0.097
R	0.696	0.013	0.187	0.004	0.603	0.012	0.790	0.016	-0.094	1.067	0.021	0.667	0.013	0.475	0.009	1.142	0.022	-0.075
S	0.828	0.016	0.199	0.004	0.317	0.006	0.516	0.010	+0.312	1.326	0.026	0.690	0.013	0.440	0.008	1.130	0.021	+0.196
T	0.753	0.014	0.167	0.003	0.644	0.012	0.811	0.015	-0.058	1.277	0.025	0.771	0.015	0.487	0.009	1.258	0.024	+0.019
T.	8.977		1.946		5.765		7.711		+1.266	14.502		8.303		5.359		13.662		+0.840
Av.	0.748	0.014	0.162	0.003	0.480	0.009	0.643	0.012	+0.106	1.209	0.023	0.692	0.013	0.447	0.009	1.139	0.022	+0.070

TABLE 2--Continued
Daily Average in Grams
Subject VI (Irradiated Milk)

Period	CALCIUM									PHOSPHORUS								
	Intake		Output						Balance	Intake		Output						Balance
			Urine		Feces		Total					Urine		Feces		Total		
	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.		Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	
A	0.800	0.015	0.108	0.002	0.728	0.014	0.836	0.016	-0.036	1.144	0.022	0.610	0.011	0.463	0.009	1.073	0.020	+0.071
B	0.773	0.015	0.113	0.002	0.599	0.011	0.712	0.013	+0.061	1.080	0.020	0.529	0.010	0.440	0.008	0.969	0.018	+0.111
C	0.733	0.014	0.127	0.002	0.700	0.013	0.827	0.015	-0.094	1.123	0.021	0.520	0.010	0.553	0.010	1.073	0.020	+0.050
D	0.762	0.014	0.119	0.002	0.747	0.014	0.866	0.016	-0.104	1.185	0.022	0.662	0.012	0.533	0.010	1.195	0.023	-0.010
E	0.773	0.015	0.115	0.002	0.804	0.015	0.919	0.017	-0.146	1.196	0.023	0.615	0.012	0.597	0.011	1.212	0.023	-0.016
F	0.828	0.016	0.077	0.001	0.713	0.013	0.790	0.014	+0.038	1.208	0.023	0.658	0.012	0.511	0.010	1.169	0.022	+0.039
G	0.754	0.014	0.115	0.002	0.511	0.010	0.626	0.012	+0.128	1.103	0.021	0.698	0.013	0.406	0.008	1.104	0.021	-0.001
H	0.741	0.014	0.085	0.002	0.408	0.008	0.493	0.010	+0.248	1.045	0.020	0.749	0.014	0.511	0.010	1.260	0.024	-0.215
I	0.769	0.015	0.097	0.002	0.594	0.011	0.691	0.013	+0.078	1.106	0.021	0.687	0.013	0.539	0.010	1.226	0.023	-0.120
J	0.809	0.015	0.124	0.002	0.705	0.013	0.829	0.015	-0.020	1.219	0.023	0.720	0.014	0.542	0.010	1.262	0.024	-0.043
K	0.857	0.016	0.120	0.002	0.618	0.012	0.738	0.014	+0.119	1.255	0.024	0.621	0.012	0.538	0.010	1.159	0.022	+0.096
L	0.709	0.013	0.108	0.002	0.691	0.013	0.799	0.015	-0.090	1.067	0.020	0.552	0.010	0.465	0.009	1.017	0.019	+0.050
M	0.820	0.015	0.117	0.002	0.657	0.012	0.774	0.014	+0.046	1.277	0.024	0.756	0.014	0.511	0.010	1.267	0.024	+0.010
N	0.552	0.010	0.108	0.002	0.889	0.017	0.997	0.019	-0.445	0.906	0.017	0.417	0.008	0.578	0.011	0.995	0.019	-0.089
O	0.725	0.014	0.123	0.002	0.601	0.011	0.724	0.013	+0.001	1.138	0.021	0.674	0.013	0.468	0.009	1.142	0.022	-0.004
P	0.765	0.014	0.115	0.002	0.455	0.009	0.570	0.011	+0.195	1.169	0.022	0.634	0.012	0.442	0.008	1.076	0.020	+0.093
Q	0.765	0.014	0.131	0.003	0.364	0.007	0.495	0.009	+0.270	1.174	0.022	0.709	0.013	0.557	0.011	1.266	0.025	-0.092
R	0.525	0.010	0.112	0.002	0.349	0.007	0.461	0.009	+0.064	0.906	0.017	0.609	0.011	0.525	0.010	1.134	0.021	-0.228
S	0.804	0.015	0.138	0.003	0.685	0.013	0.823	0.016	-0.019	1.277	0.024	0.698	0.013	0.577	0.011	1.275	0.024	+0.002
T	0.683	0.013	0.113	0.002	0.649	0.012	0.762	0.014	-0.079	1.169	0.022	0.662	0.012	0.513	0.010	1.175	0.022	-0.006
U	0.622	0.012	0.121	0.002	0.557	0.011	0.678	0.013	-0.056	1.040	0.020	0.667	0.013	0.526	0.010	1.193	0.023	-0.153
V	0.725	0.014	0.133	0.003	0.644	0.012	0.777	0.015	-0.052	1.144	0.022	0.682	0.013	0.479	0.009	1.161	0.022	-0.017
W	0.717	0.014	0.128	0.002	0.650	0.012	0.778	0.015	-0.061	1.158	0.022	0.736	0.014	0.550	0.010	1.286	0.024	-0.128
X	0.714	0.013	0.130	0.002	0.540	0.010	0.670	0.012	+0.044	1.151	0.022	0.696	0.013	0.511	0.010	1.207	0.023	-0.056
Y	0.733	0.014	0.114	0.002	0.638	0.012	0.752	0.014	-0.019	1.191	0.022	0.667	0.013	0.542	0.010	1.209	0.023	-0.018
Z	0.749	0.014	0.161	0.003	0.755	0.014	0.916	0.017	-0.167	1.143	0.022	0.711	0.013	0.555	0.010	1.266	0.023	-0.123
T.	19.207		3.052		16.251		19.303		-0.096	29.574		16.939		13.432		30.371		-0.797
Av.	0.739	0.014	0.117	0.002	0.625	0.012	0.742	0.014	-0.004	1.137	0.021	0.652	0.012	0.517	0.010	1.168	0.022	-0.031

TABLE 2--Continued

Daily Average in Grams
Subject VII (Irradiated Milk)

Period	CALCIUM									PHOSPHORUS								
	Intake		Output						Balance	Intake		Output						Balance
			Urine		Feces		Total					Urine		Feces		Total		
	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.		Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	Total	Per Kg.	
A	0.777	0.013	0.073	0.001	0.099	0.002	0.172	0.003	+0.605	1.079	0.018	0.529	0.009	0.361	0.006	0.890	0.015	+0.189
B	0.709	0.012	0.090	0.001	0.127	0.002	0.217	0.003	+0.492	1.032	0.017	0.581	0.010	0.137	0.002	0.718	0.012	+0.314
C	0.757	0.012	0.097	0.002	0.272	0.004	0.369	0.006	+0.388	1.113	0.018	0.643	0.011	0.504	0.008	1.147	0.019	-0.034
D	0.694	0.011	0.083	0.001	0.258	0.004	0.341	0.005	+0.353	1.145	0.019	0.570	0.009	0.962	0.016	1.532	0.025	-0.387
E	0.651	0.011	0.088	0.001	0.612	0.010	0.700	0.011	-0.049	1.113	0.018	0.584	0.010	0.420	0.007	1.004	0.017	+0.109
F	0.769	0.013	0.093	0.002	0.207	0.003	0.300	0.005	+0.469	1.094	0.018	0.620	0.010	0.528	0.009	1.148	0.019	-0.054
G	0.733	0.012	0.107	0.002	0.214	0.004	0.321	0.006	+0.412	1.143	0.019	0.612	0.010	0.278	0.005	0.890	0.015	+0.253
H	0.709	0.012	0.110	0.002	0.215	0.004	0.325	0.006	+0.384	1.174	0.019	0.523	0.009	0.646	0.011	1.169	0.020	+0.005
I	0.804	0.013	0.093	0.002	0.744	0.012	0.837	0.014	-0.033	1.208	0.020	0.600	0.010	0.781	0.013	1.381	0.023	-0.173
J	0.772	0.013	0.107	0.002	0.279	0.003	0.386	0.005	+0.386	1.169	0.019	0.628	0.010	1.042	0.017	1.670	0.027	-0.501
K	0.623	0.010	0.083	0.001	0.124	0.002	0.207	0.003	+0.416	1.069	0.019	0.647	0.011	0.336	0.006	0.983	0.017	+0.086
L	0.652	0.011	0.091	0.001	0.164	0.003	0.255	0.004	+0.397	1.024	0.017	0.660	0.011	0.699	0.011	1.359	0.022	-0.335
M	0.588	0.010	0.071	0.001	0.100	0.002	0.171	0.003	+0.417	0.990	0.016	0.620	0.010	0.449	0.007	1.069	0.017	-0.079
N	0.785	0.013	0.096	0.002	0.678	0.011	0.774	0.013	+0.011	1.148	0.019	0.678	0.011	0.362	0.006	1.040	0.017	+0.108
O	0.607	0.010	0.101	0.002	0.403	0.007	0.504	0.009	+0.103	1.083	0.018	0.577	0.009	0.937	0.015	1.514	0.024	-0.431
P	0.659	0.011	0.093	0.002	0.167	0.003	0.260	0.005	+0.399	1.113	0.018	0.582	0.010	0.475	0.008	1.057	0.018	+0.056
Q	0.717	0.012	0.112	0.002	0.224	0.004	0.336	0.006	+0.381	1.196	0.020	0.714	0.012	0.388	0.006	1.102	0.018	+0.094
R	0.563	0.009	0.097	0.002	0.505	0.008	0.602	0.010	-0.039	0.864	0.014	0.529	0.009	0.553	0.009	1.082	0.018	-0.218
S	0.543	0.011	0.083	0.001	0.100	0.002	0.183	0.003	+0.460	1.196	0.020	0.640	0.010	0.176	0.003	0.816	0.013	+0.380
T	0.717	0.012	0.100	0.002	.....	.....	.....	.....	.....	1.174	0.019	0.720	0.012	.....	.....	.....	.....	.....
T.	13.929		1.868		5.492		7.260		+5.952	22.127		12.257		10.034		21.571		-0.618
Av.	0.697	0.011	0.093	0.002	0.289	0.005	0.382	0.007	+0.313	1.106	0.018	0.613	0.010	0.528	0.009	1.135	0.019	-0.033

for in the control group 26.5, 24.5, and 26.3 per cent of the total calcium excretion was found in the urine; in the cod-liver oil group 32.3, and 15.7 per cent; and in the irradiated-milk group 25.2, 15.8, and 24.4 per cent. Judging from the coefficients of variation, the urinary calcium is more variable than the intakes in all except subject III, but about one-third to one-half as variable as the fecal in all cases except subject VII, where it is only one-fifth. The ranges (Table 3) of fecal calcium fall between a minimum of 0.241 gm. for subject V and a maximum of 0.935 for subject I. The average fecal excretions (except those of subject VII) for the entire experiment vary, however, within 0.185 gm. of each other; and the average excretions per kilogram of body weight vary within 0.003 gm. The wide range in fecal calcium eliminations is not at variance with those of the literature. Inaccurate division of the stools cannot account for the wide range of fecal calcium in this study, for when the coefficients of variation of the fecal calcium are compared with those of the fecal phosphorus (Table 3), the fecal calcium appears slightly more variable in subjects II and V (periods C - E), one-half to one-third more variable in subjects I, III, IV, VI, and VII, and four times more variable in subject V (periods I - T) than the fecal phosphorus even though both determinations were made from the same samples.

The total average daily output reflects the trends shown by the fecal calcium.

Calcium balance.--In determining the calcium requirements of man, Leitch ('37) states:

> Since in the normal adult, processes of storage and mobilization of calcium appear to go on continuously, it would be expected on theoretical grounds that two levels of intake might be found, one below which output would always exceed intake, and one above which the chances of a positive or a negative balance would be equal, or the loss would always be equal by the gain at another. These two might or might not coincide.

According to Leitch's analysis of the calcium balances given in the literature on normal women, the ratios of the number of negative to positive balances indicate an average maintenance requirement of about 0.55 gm. and a minimum of about 0.15 gm. at which positive balances will occur. Between these two points in any one experiment balances may be either positive or negative;

TABLE 3

ANALYSIS OF THE CALCIUM AND PHOSPHORUS DATA

Subject	Group	Periods	Number of Days	Statistics[a]	CALCIUM						PHOSPHORUS					
					Daily Average in Grams					Total Retention for Exper.	Daily Average in Grams					Total Retention for Exper.
					Intake	Output			Balance		Intake	Output			Balance	
						Urine	Feces	Total				Urine	Feces	Total		
I	Control	A-Z	130	R	0.356	0.113	0.935	0.896			0.353	0.345	0.531	0.664		
				SD	0.087	0.030	0.209	0.217			0.096	0.082	0.128	0.151		
				A	0.820	0.199	0.553	0.752	+0.069	+8.970	1.245	0.742	0.483	1.224	+0.020	+2.60
				C of V	10.612	15.075	37.793	28.856			7.718	11.051	26.501	12.337		
II	Control	A C-T	95	R	0.202	0.080	0.802	0.823			0.383	0.223	0.595	0.706		
				SD	0.064	0.021	0.168	0.237			0.100	0.060	0.143	0.176		
				A	0.742	0.170	0.525	0.695	+0.048	+4.560	1.218	0.687	0.451	1.144	+0.083	+7.885
				C of V	8.625	12.353	32.000	34.101			8.210	8.734	31.707	15.385		
V	Control	C-E	15	R	0.029	0.041	0.241	0.242			0.138	0.121	0.188	0.117		
				SD	0.015	0.023	0.125	0.133			0.069	0.062	0.094	0.065		
				A	0.694	0.157	0.440	0.597	+0.097	+1.455	1.119	0.630	0.390	1.021	+0.098	+1.470
				C of V	2.089	14.650	28.409	22.278			6.166	9.841	24.103	6.366		
III	Cod liver oil	A-I K-Z	125	R	0.673	0.138	0.375	0.449			0.495	0.221	0.205	0.323		
				SD	0.124	0.032	0.115	0.121			0.121	0.046	0.047	0.079		
				A	0.689	0.214	0.449	0.663	+0.029	+3.625	1.123	0.654	0.406	1.060	+0.061	+7.625
				C of V	17.997	14.953	25.612	18.175			10.775	7.034	11.576	7.453		
IV	Cod liver oil	A-T	100	R	0.363	0.051	0.861	0.813			0.238	0.128	0.217	0.328		
				SD	0.075	0.016	0.200	0.193			0.064	0.044	0.057	0.081		
				A	0.756	0.100	0.535	0.635	+0.121	+12.100	1.166	0.676	0.418	1.094	+0.072	+7.200
				C of V	9.921	16.000	37.383	30.394			5.489	6.509	13.636	7.404		

TABLE 3--Continued

Subject	Group	Periods	Number of Days	Statistics[a]	CALCIUM						PHOSPHORUS					
					Daily Average in Grams					Total Retention for Exper.	Daily Average in Grams					Total Retention for Exper.
					Intake	Output			Balance		Intake	Output			Balance	
						Urine	Feces	Total				Urine	Feces	Total		
V	Irrad. Milk	I-T	60	R	0.178	0.056	0.327	0.351			0.280	0.137	0.096	0.230		
				SD	0.062	0.017	0.123	0.122			0.085	0.043	0.031	0.066		
				A	0.748	0.162	0.480	0.643	+0.106	+6.360	1.209	0.692	0.447	1.139	+0.070	+4.200
				C of V	8.289	10.494	25.625	18.974			7.031	6.214	6.935	5.795		
VI	Irrad. Milk	A-Z	130	R	0.332	0.084	0.540	0.536			0.371	0.332	0.191	0.317		
				SD	0.077	0.017	0.130	0.133			0.092	0.078	0.047	0.091		
				A	0.739	0.117	0.625	0.742	-0.004	-0.520	1.137	0.652	0.517	1.168	-0.031	-4.030
				C of V	10.419	14.530	20.800	17.925			8.091	11.963	9.091	7.791		
VII	Irrad. Milk	A-S	95	R	0.241	0.041	0.645	0.666			0.344	0.197	0.905	0.814		
				SD	0.070	0.011	0.202	0.205			0.083	0.053	0.258	0.254		
				A	0.696	0.093	0.289	0.382	+0.313	+29.735	1.106	0.613	0.528	1.135	-0.033	-3.135
				C of V	10.057	11.828	69.896	53.665			7.505	8.646	48.864	22.379		

[a]R represents the range, SD the Standard Deviation, A the Average, and C of V the Coefficient of Variation.

but in practice, over any length of time there will be a net loss of calcium, increasing as the intake decreases. This observation is substantiated by the balances of the present study. Here the average daily intakes for all the subjects lie between 0.689 and 0.820 gm. The ratio of the number of negative to the number of positive balances is 1:1.36, 1:1.5, 1.27:1, 1:1.85, 1:2, 1:2, 1.6:1, and 1:5.33. If the average daily calcium balances of the subjects, both total and per kilogram of body weight, are considered as a whole, they reveal striking variations from subject to subject and from period to period. All subjects have positive balances followed by negative ones, except subject VII, who has series of large positive balances separated by single small negative balances. The negative balances occur in order and magnitude similar to those reported by Bauer et al. ('32), Bogert et al. ('22), Dye ('30), Hart et al. ('28), Hunscher et al. ('34), Kunerth et al., ('39), Kung and Yeh ('37), Pittman et al. ('39), and Ryder ('35). The intervals during which the subjects stored or lost calcium do not occur simultaneously; neither are the periods of positive or negative balance of regular duration or magnitude for a given subject. High retentions are not necessarily associated with the higher intakes, nor low retentions with the lower intakes. As would be expected, the magnitude of the negative balances for a given subject is less among the subjects (I, IV, V, and VII) who stored the most calcium. The average daily balances for the subjects in the control group were +0.069, +0.048, and +0.097 gm.; in the cod-liver oil group +0.029, and +0.121 gm.; and in the irradiated milk group +0.106, -0.004, and +0.313 gm. According to these figures, the balances were irrespective of whether the subjects served as controls or received vitamin D in the form of cod-liver oil or irradiated milk, a finding that agrees with those of Hunscher and associates ('34), Bauer and associates ('32), and Dye ('30).

Although the calcium and phosphorus loss in the menstrum was not determined, it was considered sufficiently small to make but slight change in the calcium and phosphorus balances. This supposition is verified by a calculation of the calcium and phosphorus loss in the menstrum of subjects I, II, III, and IV, who simultaneously with the present study served as subjects for an experiment in which the menstrum was collected (Leverton and Roberts, '36). From the number of cubic centimeters of blood

lost during the menstrual periods and from the blood calcium and phosphorus of these subjects (given later in Table 5), it is determined that the subjects lost respectively an average of about 3, 5, 3, and 3 mg. of calcium and 1, 2, 1, and 1 mg. of phosphorus during a menstrual period. These small amounts have but insignificant effect on the corresponding balances in which they fall. Judging from subjective observation, the menstrual losses of the other three subjects were no greater.

Calcium retention.--Despite the intervals of calcium loss, all subjects except VI stored calcium during the experiment. Subjects I, II, and V (periods C - E) of the control group retained respectively about 9.0, 4.6, and 1.5 gm. of calcium; subjects III and IV of the cod-liver oil group, 3.6 and 12.1 gm.; and subjects V (periods I - T) and VII of the irradiated milk group, 6.4 and 29.7 gm. As subject VI, of the irradiated milk group, lost about 0.5 gm., an amount so small that it could be made up in one or two experimental periods, she must have been in calcium equilibrium. If we consider the storage during periods A through T, the 100-day interval when six of the seven subjects were on the balance together, all six subjects have definite calcium retentions. Subjects I, II, III, IV, VI, and VII stored respectively about 10.3, 4.6, 5.7, 12.1, 1.1, and 29.8 gm. of calcium. These figures are not strictly comparable, for there is one period missing from each of subjects II, III, and VII.

Adequacy of the length of the experimental period.--The balances are represented graphically in Figure 3. All vertical lines above the horizontal line (which represents equilibrium) indicate the number of grams the subject is in positive balance; all those below the horizontal line, negative balance. Pictured thus, the variation in retention from period to period and from subject to subject is apparent and leads us to conclude that a 30-day balance period, which is longer than those usually employed, is not long enough to measure the calcium metabolism of the subjects in this experiment. If, for example, only a 30-day balance had been run, subject VI (irradiated milk) would have shown a loss of 1.4 gm. of calcium, whereas she actually stored 1.1 gm. during the 100-day interval. Subject IV (cod-liver oil) would have shown a retention of only 1.3 gm. of calcium and ranked fourth among the subjects in the amount of calcium stored

during the first 30 days, whereas she stored 12.1 gm. during the 100-day interval and ranked second in the amount of the element stored. The results also indicate that a period of 100 days was not long enough to justify definite conclusions regarding the calcium metabolism of the subjects. Although, at the end of this time, the subjects had been on a fairly constant diet for four months, they were still reacting differently in regard to calcium storage. The difference is not related to whether or not they served as controls or had a source of vitamin D. The three subjects--I (control), III (cod-liver oil), and VI (irradiated milk)--who were on the balance six periods (30 days) longer than the remainder were all in negative balance during this time, losing 1.48, 2.06, and 1.56 gm. of calcium respectively. This being true, they were perhaps beginning to show similar reactions.

From another point of view, a long experimental period appears necessary for measuring the calcium metabolism of these subjects. As Figure 3 clearly shows, there was an individual irregular retention and loss of calcium; and in order to avoid obtaining a balance in an interval when the individual was either definitely storing or losing calcium, the experiment had to be conducted over considerable time. If, for example, only a 30-day collection period had been run on subject I, and if it had happened to fall during the periods A through E when she was in positive balance, opposite results would have been reported from those found if the 30-day period had happened to fall during periods S through W when the balance was negative. Had a 40-day period been run on subject VI during periods F through M, the balance would have been positive; during periods S through Z, negative. Similar examples can be chosen from the graphs of other subjects. If the balances of these normal women are representative of those for other normal adults, the conflicting data of the literature regarding calcium balances are not surprising: most experiments have been fairly short, and the nutritional status of the subjects prior to the experiment (the importance of which will be discussed later) has not been considered.

Relation between the number of stools per period and the calcium retention.--As Figure 2 shows the number of stools has no relation to the calcium retention. Subjects IV and V, averaging 5 stools per period, showed a greater average retention than subjects I and II, who averaged 3. Subject III, with 7+

stools, showed a much greater retention than subject VI, with 6. Subject VII, who averaged 4 stools, stored an average of 0.313 gm. per period, an amount slightly smaller than the combined storage of the other six subjects.

Relation between the intestinal motility and the calcium retention.--Subject VII, whose intestinal motility was very sluggish, averaging 7 days for the carmine to appear in the feces (an interval 2 to 7 times as long as required for the other subjects) showed by far the greatest storage of calcium. This fact might lead one to conclude that the retention of calcium was proportional to the length of time the food remained in the intestine. It is not, however, the sole explanation, for though subjects III, IV, V, and VI had the most rapid passage of carmine through the intestine and though subjects III and VI had the least average daily storage, subjects IV and V had next to the greatest storage. Subjects I and II had comparable motility, 2 to 4 times as slow as that of subjects III, IV, V, and VI; yet their average daily storage was less than that of subjects IV and V, though greater than that of subjects III and VI. It is interesting also that subject VII retained 57.2 per cent of her total calcium storage during the first half of the experiment (periods A - J), when the average length of time required for the passage of carmine through the gastrointestinal tract was 4.5 days, as compared with 42.8 per cent storage during the latter half of the experiment (periods K - S), when the average time was 8.9 days. If calcium storage is directly related to the length of time the food remained in the intestine, then there should have been greater retention during the latter half of the experiment. Conceivably, on the other hand, up to about five days there is an increasing absorption, and at this point the body has absorbed all the calcium possible. Irrespective of how the facts may be interpreted, the subject with the slowest intestinal motility stored the most calcium--an amount ranging from about 2.5 to 20 times as much as that stored by the other subjects.

Relation between the fat content of the diet and calcium retention.--According to Hunscher and associates ('34), also Mallon and co-workers ('30), the fat content of the diet and the calcium balances manifest no relationship. Subject II, with the highest fat consumption, had an average daily balance of +0.048 gm., the subjects with intermediate fat consumption had balances of

+0.069, +0.121, +0.106, and +0.313 gm.; and the subjects, III and VI, with the lowest fat consumption, had balances of +0.029 and -0.004 gm.

Relation between physiological factors and calcium retention.--When the amount of sleep, strenuous and unusual exercise, emotional upsets, weight variations (which were slight for each subject), and menstruation are compared with the calcium balances, they appear to have had no relation to the direction, whether positive or negative, or to the magnitude of the balances.

Relation between the previous nutritional history and calcium retention.--According to Clark ('26), Daniels and co-workers ('35), Fairbanks and Mitchell ('36), Ryder ('35), and Wang and co-workers ('28), the previous nutritional history affects the retention of calcium. Histories were made of the milk consumption of the subjects and the time spent in the sunshine--the two factors most likely to influence their previous calcium and vitamin D intake. Subjects III and V customarily drank approximately 1 quart of milk daily; subject I, 3 glasses; subject II, 1 1/2 glasses (but 1 quart the previous summer); subject IV, less than a pint; subject VI, 1 glass (but she ate large quantities of cheese); and subject VII, 1 1/2 glasses for three months before the experiment (but she had a long history of even lower milk intake). Subjects I, II, and VI had spent much of the summer out of doors and had acquired good sun tans. Incidentally, subject II had gained 13 pounds at a summer camp. Subject III customarily had taken a daily dose of cod-liver oil. Subjects IV, V, and VII had spent very little time out of doors during the summer. Subject V, however, had been in the sunshine enough to obtain a slight tan.

Judging from these subjective histories and from the data, the previous nutrition of the subjects may possibly be related to the storage of calcium. Subjects I, II, III, and VI, with unquestionably good past nutritional histories in respect to milk consumption and source of vitamin D, had the lowest average daily calcium balances. They may be considered to have been in calcium equilibrium. Subjects IV and V, with nutritional histories probably inferior to those of I, II, III, and VI had higher average daily balances than the foregoing subjects and may be considered in slight positive balance. The previous diet of subject IV was rather low in milk and in vitamin D; that of V adequate in milk

but possibly somewhat low in vitamin D. Evidently subject VII, who retained calcium continuously during the entire experiment, in amount such that her average daily balance practically equalled the sum of the average daily balances of the remaining six subjects, had a nutritional history inferior to that of the others. It is unfortunate that her metabolic picture was complicated by constipation.

According to the calcium data in Table 4 all but two subjects definitely retained more calcium during the first part of the experiment than during the last. In the first 10 days the subjects stored 25, 50, 59, 1, 36, 12, and 18 per cent of the retained calcium as against -7, 4, 9, 12, 20, -46, and 8 per cent during the last 10 days. In the first 40 days 84, 1, 44, 22, 44, and 51 per cent was stored as against 7, 41, 29, 46, 15, and 29 per cent in the last 40 days; in the first half of the experiment 95, 32, 66, 41, 83, 71, and 57 per cent was stored as against 6, 68, 34, 59, 17, 29, and 43 per cent during the last half. Apparently, therefore, the calcium stores of the five subjects who retained more calcium at first than later were perhaps low, or at least not filled to capacity, at the beginning of the experiment. Since only subjective past nutritional histories are available and since many factors may influence calcium retention, it is uncertain whether the incompletely filled calcium stores of these subjects were due to a low calcium intake or to some other dietary factor. It is also difficult to explain why subjects II and IV reacted differently storing more at the last than at the first. It may or may not be significant that all subjects stored calcium during the first ten days, for I, IV, and VII, who stored the most calcium during the experiment, retained much smaller percentages during the first ten days than subjects II and III whose storage for the experiment was considerably less.

That the previous dietary history may probably have affected the calcium retention is further substantiated by the close resemblance of the average daily retentions to those of the five men prisoners studied for 28 weeks by Clark ('26). The balances of Clark's subjects were +0.027, +0.060, +0.156, +0.196, and +0.279 gm. of calcium daily. The two men with the lowest retentions had a previous history of an active out-of-door life with a diet containing adequate to optimum intake of fresh fruits and vegetables and dairy products. The average daily balances

TABLE 4

A COMPARISON OF THE PERCENTAGE STORAGE OF CALCIUM DURING INTERVALS OF PERIODS A THROUGH T

Subjects	Percentage Storage During							
	First 10 Days (Periods A-B)	Last 10 Days (Periods S-T)	First 20 Days (Periods A-D)	Last 20 Days (Periods Q-T)	First 40 Days (Periods A-H)	Last 40 Days (Periods M-T)	First Half (Periods A-J)	Last Half (Periods K-T)
I.....	25.4	- 7.2	48.1	5.4	83.9	6.9	94.6	5.5
II.....	49.6[a]	4.1	1.5[a]	2.1	1.3[a]	40.9	31.9[a]	68.1
III.....	59.1	- 9.4	53.5	-29.8	43.5	29.1	65.7[b]	34.3
IV.....	0.9	11.5	7.0	13.9	22.0	45.7	40.8	59.2
V.....	36.2[c]	20.1[d]	45.2[e]	11.1[f]	....	....	82.9[g]	17.1[h]
VI.....	11.6	-45.6	-80.5	109.8	44.2	15.4	71.2	28.8
VII.....	18.4	7.7[i]	30.9	13.5[i]	51.3	29.1[i]	57.2	42.8[i]

[a]Period B missing. [b]Period J missing. [c]Periods I-J.

[d]Periods S-T. [e]Periods I-L. [f]Periods Q-T.

[g]Periods I-N. [h]Periods O-T. [i]Period T missing.

of subjects I and III of this experiment closely agree with those of these two men. The average daily balance of subject II falls in between that of the same two men and that of VI falls below. Subjects I, II, III, and IV had histories of at least adequate milk consumption and a source of vitamin D. The average daily balances of IV and V were about half that of the next highest retention of Clark's subjects (a man with some milk in his previous diet); and to judge from their former nutritional histories, their diet was better than this subject's. The average daily retention of subject VII is practically the same as the highest retention reported by Clark, that of a man, who, like VII, had the poorest nutritional history. It is interesting that Clark's subjects with the two lowest retentions and the best nutritional histories had negative calcium balances comparable in magnitude and occurrence with those of I, II, III, IV, V, and VI of this experiment. His subjects with highest retentions and with poor nutritional histories had but one or two very small negative balances, as did subject VII.

Relation between vitamin D and calcium retention.--Evidently the calcium intake approached the liberal allowance recommended by Sherman, and the diet as a whole was favorable to calcium storage. As to the effect of vitamin D on retention, apparently no more calcium was stored by the subjects who received the vitamin than by the controls; on the other hand, there is no proof that the vitamin did any harm. It is regrettable that the experiment could not have continued throughout a calendar year in order to determine whether the subjects eventually would have had uniform calcium retentions; whether the irregular intervals of losses and retentions would have continued; and whether the calcium retention would have varied seasonally.

Phosphorus Analysis of Food and Excreta

The phosphorus results are summarized in Table 2, treated statistically in Table 3, and represented graphically in Figure 4.

Phosphorus intake.--The phosphorus intake varied, as did the calcium intake, but no more than would be expected from the type of diet employed. Although the ranges of the period intakes for the different subjects (Table 4) fall between 0.138 and 0.495 gm., with an average range of 3.9 gm., the average daily intakes

for the experiment agree fairly closely, the values being 1.246, 1.218, 1.119, 1.123, 1.166, 1.209, 1.137, and 1.106 gm. The coefficients of variation lie between 5.5 and 10.8 and give further indication of fair agreement between the phosphorus intakes. On the kilogram-of-body-weight basis the average daily intakes for the different subjects are 0.021, 0.020, 0.022, 0.025, 0.022, 0.023, 0.021, and 0.018 gm. Here, again, the variability is small.

Phosphorus output.--The coefficients of variation disclose more consistency in the average daily urinary, fecal, and total phosphorus output of each subject than in the calcium excretions, and also less variability in the urinary than in the fecal output. Although variations from period to period are apparent, the subjects agree rather closely in the average daily urinary phosphorus, the values being 0.742, 0.687, 0.630, 0.654, 0.676, 0.692, 0.652, and 0.613 gm. The same is true of the average daily fecal phosphorus--0.483, 0.451, 0.390, 0.406, 0.418, 0.447, 0.517, and 0.528 gm.; and also of the average daily total phosphorus excretions--1.224, 1.144, 1.021, 1.060, 1.094, 1.139, 1.169, and 1.135 gm. Agreement is likewise shown by the average daily outputs per kilogram of body weight--0.021, 0.019, 0.020, 0.024, 0.020, 0.022, 0.022, and 0.019 gm.

Phosphorus balance.--The phosphorus balances agree with those of Hunscher and co-workers ('34), Ryder ('35), and others. The data and the graphs of the balances reveal individual variations in the retention of phosphorus from period to period. As with the calcium balances, there are negative balances among the subjects who had a storage of phosphorus at the end of the experiment. The negative balances of the subjects differ from the negative calcium balances, being fewer and smaller. Of the individuals who were in approximate phosphorus equilibrium or were showing slight storage or loss--subjects I, VI, and VII--the negative balances were more numerous and greater. Conversely, subjects definitely storing phosphorus had but few negative balances of relatively small magnitude.

Phosphorus retention.--The average daily phosphorus retentions for the control group (subjects I, II, and V) are +0.020, +0.083, and +0.098 gm.; for the cod-liver oil group (III and IV), +0.061, and +0.072 gm.; and for the irradiated milk group (V, VI, and VII), +0.070, -0.031, and -0.033 gm. The total retention of

subject I, +2.6 gm.; II, +7.9 gm.; III, +7.6 gm.; IV, +7.2 gm.; V, +1.5 gm. (periods C - E) and +4.2 gm. (periods I - T); VI, -4.0 gm.; and VII, -3.1 gm. Judging from these retentions, vitamin D apparently did not affect the retention of phosphorus, and the phosphorus retentions as a whole are less than the calcium retentions.

Relation between various physiological factors and phosphorus retention.--As with the calcium data, there is no correlation between the phosphorus retention and intestinal motility, number of stools, hours of sleep, strenuous physical exertion, or emotional disturbances. As for the effect of the previous nutritional histories on the phosphorus retentions, apparently the subjects' body stores had been more amply filled with this element than with calcium, for their previous dietary had not indicated a phosphorus shortage. Further confirmation is the fact that, except in subject III, there is no greater percentage storage during the first than during the latter part of the experiment.

Relation between the Calcium and Phosphorus Retentions

Even though calcium and phosphorus are definitely associated in skeletal changes, their other functions of bodily maintenance are distinctly separate. There is little relationship to be noted under the experimental conditions of the present study. The levels of calcium and phosphorus storage by each subject, except VII, for a given period were at times approximately the same; but, at times almost equally frequent, the calcium retention was higher than the phosphorus, or vice versa. The average daily retentions of phosphorus exceeded the calcium retentions in subjects II, III, and V (control interval) by 0.035, 0.032, and 0.001 gm. respectively; but in I, IV, and V (irradiated milk interval) the average daily calcium retentions exceeded the phosphorus retentions by 0.049, 0.049, and 0.036 gm. Subject VII reacted differently: in only one period during the experiment did the phosphorus retention exceed the calcium. The average daily calcium storage exceeded the phosphorus by 0.346 gm. It is most unusual that this subject, who was constantly storing relatively large amounts of calcium, was in slight negative phosphorus balance. Since much of the retained calcium would be expected to be laid down as cal-

cium phosphate in the bones and would therefore require phosphorus for its deposition, one may logically ask whether the body store of phosphorus could be large enough to care for this great retention of calcium. Such a condition might be possible: as Sherman ('39) and as McCollum and co-workers ('39) have pointed out, a larger quantity and proportion of phosphorus are associated with the active tissues of the body than with calcium in the bones. The previous dietary history of this subject gave no indication of phosphorus shortage as it did of calcium shortage. Possibly, then, there was a storage of phosphorus, over and above that combined with calcium in the bones, large enough to meet the needs of further calcium deposition. That calcium and phosphorus can be retained independently has been demonstrated by Nicolaysen ('37). On a phosphorus-free diet, D-deficient rats absorbed 50, 36, and 28 per cent of the calcium in the diet as compared with 100, 57, and 47 per cent by the rats receiving the same diet but supplemented with 50 I.U. of vitamin D daily. In calcium starvation, absorption of phosphorus from inorganic phosphate, glycerophosphate, and caseinogen was complete both in normal and in vitamin-D deficient rats.

In Kung and Yeh's ('37) study on Chinese women, four of the five subjects retained more calcium than phosphorus on intakes of 0.419 gm. calcium and 0.972 gm. phosphorus; and two of the subjects with positive calcium retentions had negative phosphorus retentions. In Owen's ('39) investigation of ten adults, over an interval of 9 experimental days the calcium retention exceeded the phosphorus in nine of the subjects on intakes of about 0.879 gm. calcium and 1.227 gm. phosphorus, and four of the subjects with positive calcium retentions had negative phosphorus retentions. That the individual calcium and phosphorus retentions do not closely parallel one another is borne out by other investigators (Bower et al., '32; Pittman, '32; Kramer et al., '28; Clark, '26, Kunerth and Pittman, '39; and Pittman and Kunerth, '39).

Blood Calcium and Phosphorus

The blood calcium and phosphorus determinations in Table 5 reveal slight individual variations. The values all lie in the normal range of 9 to 11 mg. of calcium and 3 to 4 mg. of phosphorus per 100 cc. of serum (Hawk, '31; and Mull, '32). The

TABLE 5

BLOOD CALCIUM AND PHOSPHORUS

	Calcium		Phosphorus	
	Menstrual	Inter-menstrual	Menstrual	Inter-menstrual
	mg. per 100 cc.	mg. per 100 cc.	mg. per 100 cc.	mg. per 100 mg.
Subject I	10.2	10.1	3.9	4.0
	10.1	10.0	3.8	3.9
	10.3	10.1	4.0	4.0
	10.2	10.0	3.9	4.0
	10.1	....	4.0	...
Average	10.2	10.1	3.9	4.0
Subject II	10.0	9.8	4.0	4.0
	10.1	9.8	4.9	4.0
	10.0	....	4.0	...
Average	10.0	9.8	4.0	4.0
Subject III	9.8	9.6	3.5	3.8
	9.6	9.5	3.4	3.4
	9.8	9.6	3.8	3.6
	9.9	....	3.6	...
Average	9.8	9.6	3.6	3.6
Subject IV	10.0	9.8	3.6	3.6
	9.8	9.6	3.7	3.8
	9.7	9.6	3.5	3.7
	9.9	....	3.8	...
Average	9.9	9.7	3.7	3.7
Subject V	10.1	10.0	3.9	3.7
	10.2	9.9	4.0	3.9
	10.1	9.9	4.0	3.8
	....	9.8	...	3.9
Average	10.1	9.9	4.0	3.8
Subject VI	10.1	9.8	3.7	3.9
	10.1	9.7	3.8	3.7
	10.1	9.9	3.8	3.8
	10.2	....	3.9	...
Average	10.1	9.8	3.8	3.8
Average of the six subjects	10.0	9.8	3.9	3.8

serum calcium was a little lower midway of intermenstrual periods than during the menstrual periods; this fact is in accordance with Pucher and co-workers ('34). The average of the serum calcium for all subjects during the menstrual periods was 10.0 mg. and during the intermenstrual periods 9.8 mg. as compared with Pucher's averages of 10.2 and 9.9 mg., each value of which represents the average of thirteen observations on two subjects. The findings are not contradicted by those of the literature taken from more comprehensive blood calcium studies in which samples were withdrawn at more frequent intervals. According to such studies, made on small numbers of women, though the changes in concentration of serum calcium at any phase of the monthly cycle are not outstanding, there is gradual decrease during the postmenstrual period with a gradual rise in the premenstrual period attaining a maximum value just before the flow (Bock, '28; Boyton and Greisheimer, '31; and Maters, '29). In an experiment on twelve healthy women in which blood samples were drawn three times a week for about 5 weeks, Okey and co-workers ('30) found only small changes in the concentration of serum calcium, but noted a tendency to a frequency of low values for calcium a few days before the onset of menstruation and to a frequency of higher values from the 8th to the 15th days after the onset of menstrual bleeding. The only evidence that in part disagrees with the foregoing investigators is that of Allen and Goldthorpe ('29), who found slight variations in the blood calcium level of normal women but detected no appreciable or constant effect on the calcium level by menstruation. A comparison of the blood calcium and phosphorus with the calcium and phosphorus balances reveals neither a parallel nor a lag relationship.

SUMMARY

A calcium-phosphorus metabolic study was made on healthy young women living on an adequate mixed diet with the minerals in question held at a fairly constant level. The experiment was divided into consecutive 5-day balance periods, conducted over an interval of 75 to 130 days and preceded by a 10-day preliminary period. All subjects received the same basal diet and satisfied their individual energy requirements with high caloric foods low in calcium and phosphorus; three served as controls;

two had a daily dose of cod-liver oil; and three drank irradiated milk in place of the regular pasteurized milk of the basal diet.

Throughout the experiment there was an individual variation in retention of calcium and phosphorus. Calcium retentions were, as a whole, more variable and of greater magnitude than phosphorus retentions. Irrespective of the amount of calcium stored, there were intervals of definite retention and loss over varying intervals (some as long as 40 days). The amount of calcium retained was probably affected by the body stores of the element as related to the previous diet over rather long intervals. High retentions were associated with a history of low calcium intake and vice versa. The daily consumption of 945 U.S.P. units of vitamin D in cod-liver oil or 67.5 U.S.P. units of vitamin D in irradiated milk did not affect the retention of calcium or phosphorus nor the level of these elements in the blood; there is, however, no evidence that it did harm. Blood calcium was slightly higher during the menstrual periods than midway of the menstrual cycle.

CONCLUSIONS

Under the conditions of this experiment the following appears to be true of the normal adult woman:

1. Widely varying amounts of calcium and phosphorus on a practically constant general mixed diet are stored over an interval at least as long as five months.

2. The calcium retentions as a whole are more variable and of greater magnitude than the phosphorus retentions.

3. Irrespective of the amount of calcium stored over long periods, individuals have irregular retentions and losses of calcium over varying intervals (some as long as 40 days).

4. The individual variation in the calcium retentions is possibly affected by the condition of the body stores of the element as related to the previous diet over fairly long periods. High retentions are associated with a history of low calcium intake and vice versa.

5. The daily consumption of 945 U.S.P. units of vitamin D in the form of cod-liver oil or 67.5 U.S.P. units of vitamin D in the form of irradiated milk apparently does not affect the retention of calcium and phosphorus or the level of these ele-

ments in the blood; however, there is no evidence that it does harm.

6. Blood calcium is slightly higher during the menstrual periods than midway in the menstrual cycle.

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